P.E.I. 35

EVALUATION OF THE KINGS COUNTY MEMORIAL HOSPITAL WOOD FIRED HEATING SYSTEM AND WOOD CHIP FUEL SUPPLY ALTERNATIVES

VOLUME 1: FINAL REPORT

for the

Prince Edward Island Energy Corporation
Charlottetown, Prince Edward Island

Edited by

Resource Ventures Incorporated
49 Pownal Street
Charlottetown, P.E.I., C1A 3W2

Prepared by

IEA Consulting Group Ltd.
71 Water Street
Charlottetown, P.E.I., C1A 1A4

NOVEMBER 1983

Resource Ventures Incorporated is a wholly owned subsidiary of the Institute of Man and Resources

TABLE OF CONTENTS

		Page
1.0	EXECUTIVE SUMMARY	1
2.0	INTRODUCTION	2
3.0	TERMS OF REFERENCE	
	3.1 Measurement and Recording of Moisture Content of Delivered Wood Chips	3
	3.2 Measurement of Chip Burner Performance (Acceptance Test)	3
	3.3 Evaluation of the Chip Burning System	3
	3.4 Evaluation of the Harvesting Operation	3
	3.5 Wood Chip Drying and Monitoring	4
4.0	SYSTEM OPERATION	4
5.0	WOOD CHIP FUEL - MOISTURE CONTENT ANALYSIS (WET BASIS)	8
6.0	WOOD FUEL STORAGE	
	6.1 Initial Approach and Furnace Start-Up	10
	6.2 Wood Chip Drying and Monitoring	14
	6.2.1 Preparatory Work	16
	6.2.2 Information Collection	16
	6.2.3 Wood Chip Quantities	17
	6.2.4 Moisture Content	17
	6.2.5 Wood Chip Storage Temperatures	18
	6.2.6 Results	19
	6.2.7 Conclusions	19
	6.2.8 Recommendations	20
7.0	WOOD CHIP FUEL DELIVERY	20
8.0	WOOD FUEL HARVESTING PROCESS	
	8.1 Wood Fuel Production	22
	8.1.1 The Iris Block	22
	8.1.2 The Cambridge Block	24
	8.1.3 The Brudenell Block	25
	8.2 Fuelwood Harvesting Practices	25
	8.2.1 The Iris Block	25
	8.2.2 The Cambridge Block	27
	8.2.3 St. Mary's Road Block	27
	8.2.4 The Brudenell Block	27
	8.3 Evaluation	28
	8.4 Recommendations	29
	8.5 References	30

TABLE OF CONTENTS (Continued)

Page

9.0 SYSTEM MAINTENANCE

9.1 General 30
9.2 De-Ashing 30
9.3 Twigs and Oversize Chips 30
9.4 Lubrication 32
9.5 Stack Drain 32
9.6 Boiler Tube Cleaning 32
9.7 Hydraulic Scraper System 32
9.8 Induced Draft Fan 32

10.0 SYSTEM PERFORMANCE - OPERATIONAL

10.1 General 32
10.2 Incident Report 33
10.3 Reliability 34
10.3.1 Auger Jamming 34
10.3.2 Overfire/Underfire Fans 34
10.3.3 Twigs and Branches 34
10.3.4 Major Failures 34
10.3.5 System Back-up 34

11.0 TECHNICAL EVALUATION 35

12.0 ELECTRICAL CONSUMPTION 36

13.0 KCMH - ECONOMIC EVALUATION

13.1 Objectives 39
13.2 Methodology 39
13.2.1 Operating Costs 39
13.2.2 Labour Impact 39
13.2.3 Forest Industry Impact 39
13.2.4 Capital Budgeting Analysis 40
13.2.5 Fuel Oil Displaced 40
13.3 Evaluation Results 40
13.3.1 Operating Costs 40
13.3.2 Labour Impact 45
13.3.3 Forestry Industry Impact 47
13.3.4 Capital Budgeting Analysis 47
13.3.5 Fuel Oil Displaced 50

14.0 CONCLUSIONS 50

15.0 RECOMMENDATIONS 51

LIST OF FIGURES AND EXHIBITS

		Page
FIGURE 1	Kings County Memorial Hospital Wood Chip Fired Boiler (Schematic)	6
FIGURE 2	Energy Content of Wood Chip Fuel (Effect of Moisture)	9
FIGURE 3	Wood Chip Moisture Determination Chart	11
FIGURE 4	Extract from a Wood Chip Moisture Determination Analysis	13
FIGURE 5	Wood Chip Moisture Content Analysis Sheet for April 9-14, 1982	15
FIGURE 6	Boiler Room Report Form	31
EXHIBIT 1	Locations and Configurations of Wood Harvesting Operation Blocks	23
EXHIBIT 2	Comparison of Fuel Production Methods	26

LIST OF TABLES

		Page
TABLE 13-1	Kings County Memorial Hospital Record of Fuel Oil Delivery (1980/81)	41
TABLE 13-2	Kings County Memorial Hospital Record of Fuel Oil Delivery (1981/82)	42
TABLE 13-3	Conversion of Actual Wood Chip Fuel Deliveries to Equivalent Amount of Fuel Oil	44
TABLE 13-4	Comparison of Operating Costs	46
TABLE 13-5	Financial Analysis	48

APPENDICES

See VOLUME 2: APPENDICES FOR THE FINAL REPORT

1.0 EXECUTIVE SUMMARY

To help to establish a wood fuel industry in Prince Edward Island, the Prince Edward Island Energy Corporation, with the support of the Canada/Prince Edward Island Comprehensive Development Plan, established a demonstration project to convert the heating system at the Kings County Memorial Hospital from oil to wood chip fuel. Monitoring, evaluation and technology transfer aspects of the project were supported by Energy, Mines and Resources Canada and the Energy Corporation.

An Anga and Varme wood chip fueled boiler was chosen for installation in a boiler room added to the hospital. Performance of the system was evaluated by short-term thermal tests and by measuring fuel inputs and steam production over a full heating season. The evaluation included analyses of the effects of alternative production, transportation and storage methods on fuel quality and cost. The effect of the installation on the forest resource was also evaluated.

The heating unit performed essentially as specified by the supplier. It was found to be capable of displacing essentially all of the oil previously used with little or no increase in labour requirements. The operating staff has accepted the equipment completely. Rate of return for this project is expected to be about 12%, resulting in a payback period of ten years or less. Other similar projects may be eligible for grants of up to 20% of capital cost from the federal Forest Industry Renewable Energy program and result in rates of return of up to 15%. The rate of return may be further increased by reductions in capital cost in repeat systems and from tax effects. Governments may also realize external benefits from jobs, forest impacts and reductions in oil imports.

The wood fuel supply system performed well: there were no shut downs resulting from fuel shortages. Experience with outdoor chip storage and an evaluation of alternative supply systems suggested that a "cold decking" approach (full trees piled after felling for later chipping), with short-term storage to carry supplies through inclement weather, would be the most effective means of supplying wood chip fuel.

Full tree harvesting was found to leave a harvesting site in condition for replanting without further treatment. This results in a

saving of about $150/ha ($60/acre) compared to normal harvesting methods, equivalent to over $1/tonne of chips produced.

2.0 INTRODUCTION

In October 1981, the P.E.I. Energy Corporation established a project under the Canada/P.E.I. Comprehensive Development Plan to convert the heating system of the Kings County Memorial Hospital (KCMH) in Montague, P.E.I. to a wood chip fueled system.

The KCMH was selected for conversion because:

a) the potential for fuel savings/oil substitution was relatively high, in the order of 450,000 litres per year, and

b) the hospital had its own laundry facilities and consequently the demand for heat was significant on a year round basis.

The conversion of the heating system required the construction of an addition to the boiler room to house the new furnace and to provide storage space for a one week supply of wood chip fuel. A one week supply consists of approximately 50 tonnes (145 m^3). The furnace was supplied and installed by Anga and Varme (A & V) Canada Ltd. The A & V specification for the system is included in Appendix A. Construction took place during the autumn and winter of 1981/82 and the system first went into operation on May 8, 1982.

The wood chip fuel was harvested and stored under a contract with J.O. Hornby Ltd. of Hunter River, P.E.I.

During the course of the demonstration it became evident that more information on the preparation, storage and delivery of wood chip fuel was needed. A separate project to explore alternative approaches to providing wood chips was therefore initiated.

Energy, Mines and Resources Canada and the Energy Corporation supported the evaluation, monitoring and technology transfer aspects of the project.

The services of IEA Consulting Group Ltd. were retained to carry out an evaluation of the system and to examine wood chip supply issues. This report presents the results of the heating system evaluation and the wood chip supply examination.

3.0 TERMS OF REFERENCE

3.1 Measurement and Recording of Moisture Content of Delivered Wood Chips

A procedure will be put in place to accurately and efficiently measure and record the moisture content of the wood chips delivered to the hospital. The present fuel contract specified payment on the basis of moisture content. The extra costs incurred by this method will be compared to the purchasing of fuel wood at a fixed price per ton.

3.2 Measurement of Chip Burner Performance (Acceptance Test)

After initial start-up the chip burner will be evaluated to assess its performance against the manufacturer's stated claims for output and efficiency, under a variety of loads and fuel moisture content levels. Electrical consumption, the efficiency and output of the existing oil-fired boilers will also be measured to provide base-line data for evaluating the entire system.

3.3 Evaluation of the Chip Burning System

A number of subjective and objective measurements will be made to monitor the system performance during periods of continuous operation. The evaluation will assess and project:

- reliability
- maintenance
- fuel consumption
- ease of operation
- steam energy delivered
- electrical energy consumed
- economic benefits

3.4 Evaluation of the Harvesting Operation

A schedule of visits to the chipping and chip storage site will be developed to assess the methods of chip production, chip storage, handling and transport employed by the current wood chip contractor, J.O. Hornby.

Quarterly reports will be submitted discussing:

- fuel quality
- wood chip storage methods
- fuel wood harvesting and chipping operations
- silviculture management
- operating costs and efficiencies

3.5 Wood Chip Drying and Monitoring

This project included a study of two approaches to drying the wood chip fuel.

1) An outdoor, conical pile prepared directly on the ground had air blown through it by a gasoline motor driven blower and underpile ventilation system.
2) A wood chip pile in an unheated warehouse had air blown through it by an electrically driven blower and underpile ventilation system.

4.0 SYSTEM OPERATION

The Anga & Varme wood chip burning heating plant is almost fully automatic, requiring only a small amount of daily and scheduled maintenance for such things as oversize chip removal from the transfer screws, ash clearance and boiler tube cleaning. Following is a description of each of the major tasks associated with the operation of the unit:

a) Fuel Delivery

Wood chip fuel is collected from the fuel storage area located nearby, transported by dump truck and delivered to the fuel silo located next to the hospital furnace room. During transport each load was to be weighed and a weigh bill provided to the Hospital stationary engineer.

In practice this did not always occur. The weigh scales used were located at:

a) the Roseneath grain elevator which was open during specified hours with priority to grain haulers, and
b) the Langley warehouse and were open only if prior arrangements could be made.

As a consequence loads were not always weighed. During the winter one truck, a 10 ton dump, was allocated to the wood chip transport task and it was normally parked in the fuel storage warehouse. The weight of this truck was known, 20,100 lb (9117 kg), as well as the volume 500 ft^3 (±10 ft^3), or 14.15 m^3 (±0.3 m^3).

While fuel is being unloaded, the transport operator extracts from each load, two samples of fuel for moisture content analysis. These samples are delivered to the hospital stationary engineer, who is responsible for completing the moisture content analysis. In the heating plant a sample of approximately 800 grams was selected from the sample provided by the transport operator and immediately tested for moisture content. The immediate testing ensured that any moisture content change between the time the sample was taken and the moisture content analysis was minimal. The moisture content analysis procedure is discussed in section 5.0.

At the hospital the fuel is dumped onto a steel grill through which it falls into the silo below (see Figure 1). The fuel unloading procedure provides the truck operator with the opportunity to remove any obvious oversize chips, branches or other objects which have been missed by the chipper and which might later interfere with the furnace stoking operation. The grill mesh size is 38 cm x 13 cm.

b) Furnace Stoking System

In the fuel silo the wood chips are "scraped" forward by hydraulically driven scrapers. The chips pass under a concrete bridge wall at the forward end of the fuel silo and fall into a cross auger which moves them to an inclined auger. A photo in the photographic record, Appendix B shows the interior of the fuel silo. Figure 1 shows the general arrangement of the fuel silo scrapers, bridge wall and cross auger. An overfeed sensor located at the end of the cross auger controls the action of the fuel silo scrapers and the cross auger (see Figure 1). A pendulum type sensor located at the exit from the fuel silo (and entrance to the cross auger) provides an emergency shut down of the hydraulic scraper in the event of an over filling of the cross auger. At the end of the cross auger, an inclined auger picks up the fuel and carries it over and above the main furnace stoker auger. The photographs in the photographic record, Appendix B show the inclined auger. This auger is also controlled by an overfeed sensor.

KINGS COUNTY MEMORIAL HOSPITAL

Wood Chip Fired Boiler

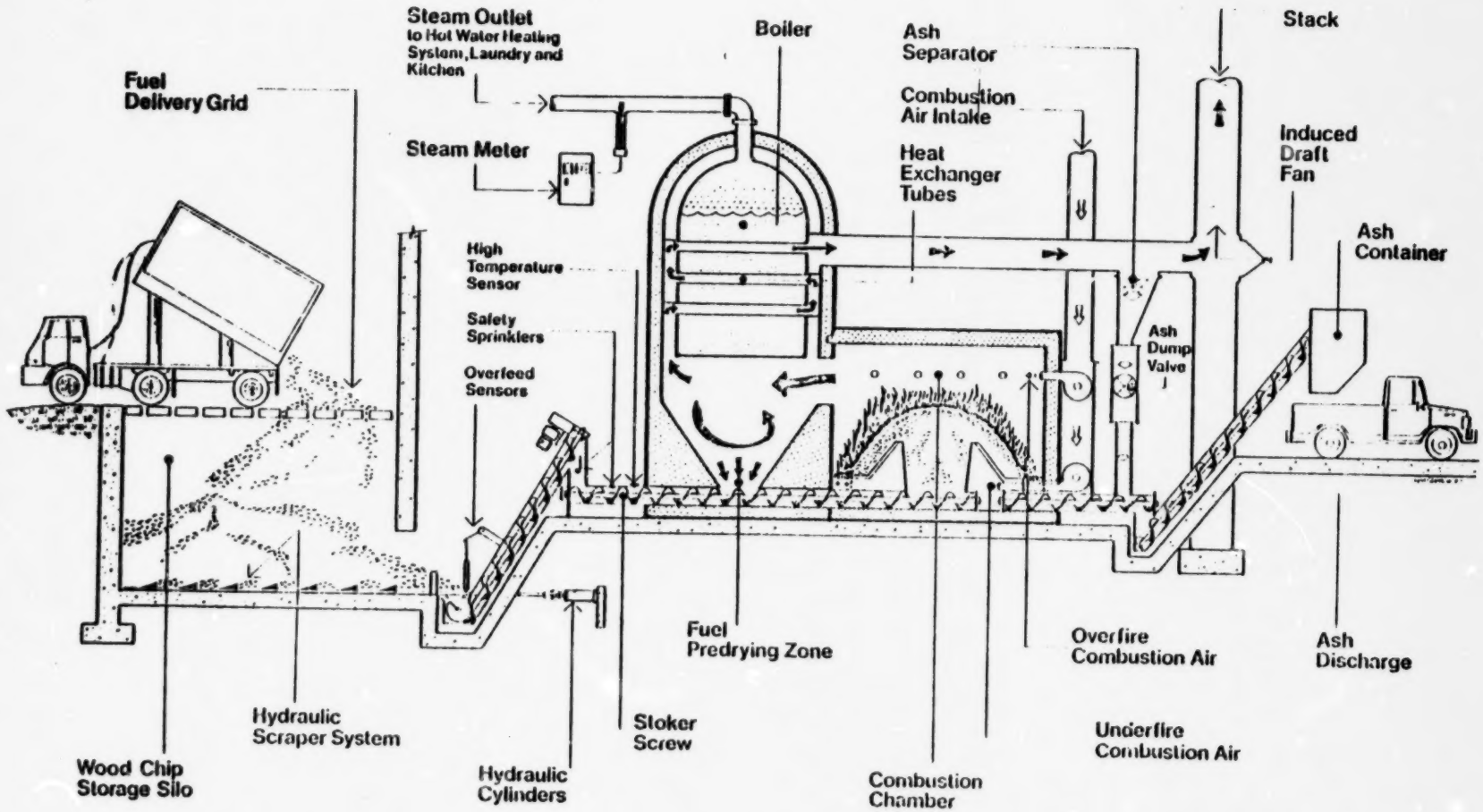


FIGURE 1

The main stoker auger is not clearly visible except for one short section under and alongside the inclined auger. However, Figure 1 shows the relationship of the main auger to the inclined auger and the combustion chamber. Reversing flukes (not shown) on the end of main feed auger ensure that all chips are forced up into the combustion chamber. The main stoker auger is controlled from an adjustable "high-fire" timer in the main control panel which is activated on a fall in boiler steam pressure. It is also activated by a second adjustable "low-fire" timer in the "hold-fire" mode.

c) Combustion Process

Combustion takes place a short distance from the steam boiler in a refractory lined, insulated chamber called a fuel cell.

Wood chip fuel is delivered from the main stoker auger through a circular opening in the conical shaped floor of the fuel cell. Underfire air is provided through holes in the cone and through slots in the floor. Overfire or secondary air is provided through holes in the wall of the fuel cell.

Figure 1 outlines the path of the fuel and combustion gases. A photograph of the interior of the fuel cell is included in the photographic record in Appendix B.

Combustion in the fuel cell provides time for a more complete combustion process before the gases are cooled in the boiler. Temperatures in the fuel cell can be in excess of 1000°C.

The manufacturer does not recommend the use of wood chips with less then 25% moisture content since to do so would permit excessively high temperatures in the fuel cell. Overheating in the fuel cell could damage its refractory lining.

d) Ash Removal

The furnace operator, working through the furnace door, manually rakes ash from around the fire into ash pits in the floor of the fuel cell. From these pits ash is then dropped into an under-floor auger which transports it to a second inclined auger. The inclined ash auger then carries the ash outside and deposits it in an exterior ash container. Figure 1 contains a sketch of the ash removal system. Photographs of the ash removal system are contained in Appendix B.

Ash is removed from the fuel cell once each day during the last shift and the exterior ash container is emptied by a sub-contractor once each

week. The quantity of ash produced is relatively small amounting to approximately 0.2 m^3 per week. The exterior container can accept up to 0.5 m^3 before having to be emptied.

Fly ash from the flue gas is collected at the furnace breeching and at pre-set intervals is passed through an ash dump valve (air-lock) into the inclined ash removal auger. From there fly ash is conveyed to the exterior ash container.

e) Furnace Control

A central control panel contains the various control elements which manage the operations of the primary and secondary air supply, induced draft fan, fuel feed auger and ash removal auger.

5.0 WOOD CHIP FUEL - MOISTURE CONTENT ANALYSIS (WET BASIS)

As part of this project it was necessary to devise a means of accurately measuring and recording the moisture content of the wood chips delivered to the hospital. A system of moisture content measurement was essential because:

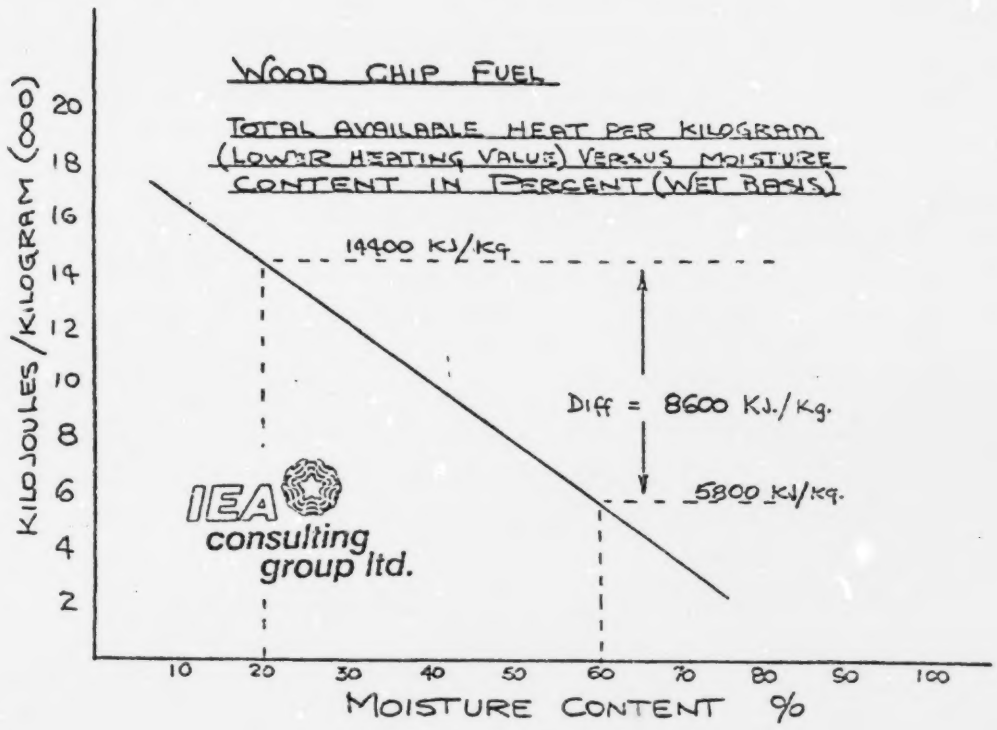
a) the performance of the furnace was based on having wood chips with a moisture content of not less than 25% and not greater than 55%, and

b) while the nominal price for wood chip fuel was based on a moisture content of 43%, the price was adjusted to the weight of dry fuel delivered for other moisture contents.

The effect of a high amount of moisture in wood fuel is to reduce the amount of heat available from any given unit (kg, ton, etc.) of fuel. As the moisture content in a unit of fuel increases, more and more of the available energy is utilized in boiling off this moisture. Finally, at approximately 85% moisture content (if the fuel can be made to burn) all of the energy in the fuel will be dissipated in boiling off the water and none will be available for other uses. This effect is graphically shown in Figure 2.

The method established for the measurement of moisture content is described below:

(i) Two samples of wood chips are taken (two buckets) from each load of chips delivered to the fuel silo at the hospital.


WOOD CHIP FUEL
TOTAL AVAILABLE HEAT PER KILOGRAM (LOWER HEATING VALUE) VERSUS MOISTURE CONTENT IN PERCENT (WET BASIS)
KILOJOULES/KILOGRAM (000)
20
18
16
14
12
10
8
6
4
2
19400 KJ/Kg.
Diff = 8600 KJ./Kg.
5800 KJ/Kg.
IEA consulting group ltd.
10 20 30 40 50 60 70 80 90 100
MOISTURE CONTENT %

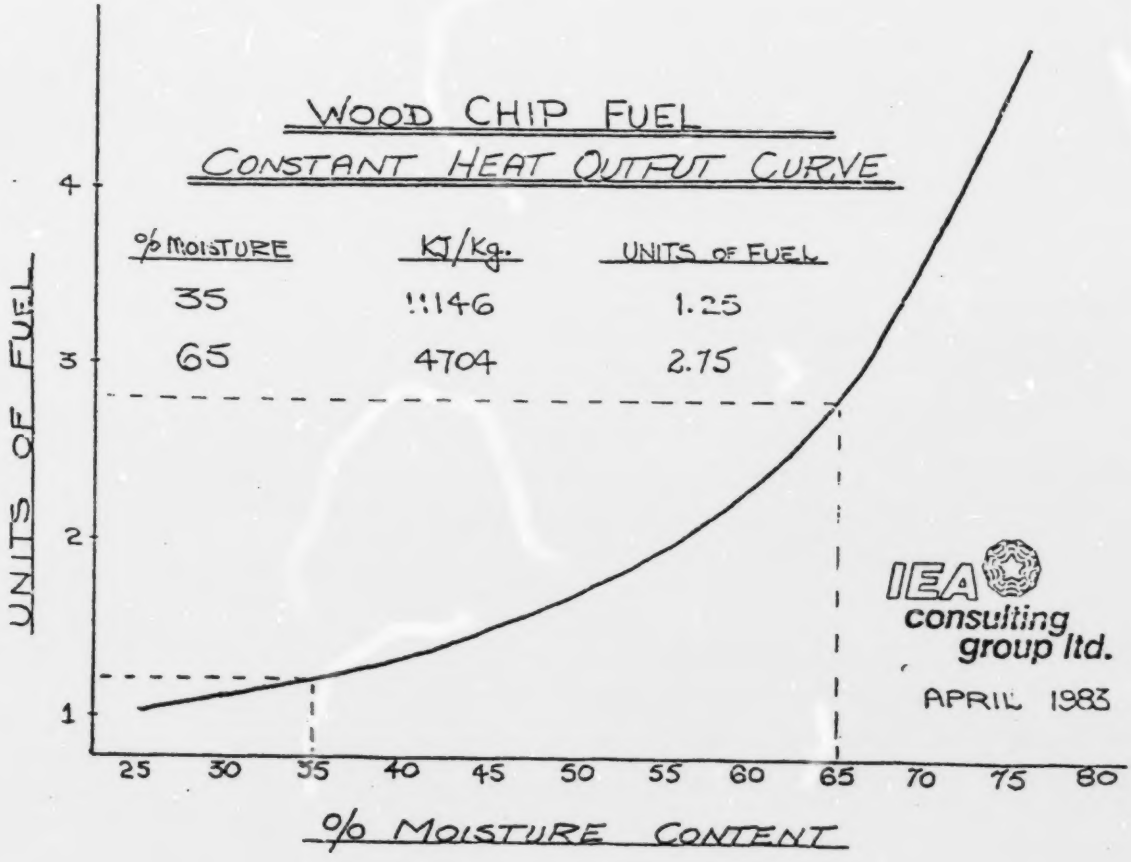

WOOD CHIP FUEL
CONSTANT HEAT OUTPUT CURVE
% MOISTURE
KJ/Kg.
UNITS OF FUEL
35
4146
1.25
65
4704
2.75
UNITS OF FUEL
4
3
2
1
IEA consulting group ltd.
APRIL 1983
25 30 35 40 45 50 55 60 65 70 75 80
% MOISTURE CONTENT

FIG 2

(ii) These wood chips are placed in trays from a Williams Standard Pulp testing oven. These trays each have a known and recorded weight. A copy of the specifications for the Williams oven is included in Appendix C.

(iii) The tray and chips are then accurately weighed using an "OHAUS Heavy Duty Solution Balance" and the weight is recorded on a chart. (A copy of the chart is shown in Figure 3). A specification sheet on the OHAUS balance is included as Appendix D.

(iv) The tray is placed in the drying oven and dried for a period of 24 hours at 110°C.

(v) The tray is removed from the oven, carefully re-weighed and returned to the oven for a further 4 hours at 110°C. The purpose of the second drying is to ensure that all of the moisture has been driven off and that a stable condition has been reached.

(vi) The moisture content of the fuel is calculated:

$$\frac{\left(\text{wet weight of the fuel and tray} - \text{weight of the tray}\right) - \left(\text{dry weight of the fuel and tray} - \text{weight of the tray}\right)}{\text{wet weight of the fuel and tray} - \text{weight of the tray}} =$$

(vii) The calculated moisture content is then entered on the chart.

Information on load weigh bill numbers and moisture content is then passed on to the financial authority to permit payment to be initiated.

6.0 WOOD FUEL STORAGE

The subject of wood fuel storage became one of the most widely discussed topics within the project because:

a) storage conditions affect moisture content; and

b) moisture content affects furnace performance.

6.1 Initial Approach and Furnace Start-Up

At the initiation of the project is was decided to store the wood chips out of doors in large piles at the site where the chips were produced. The decision to use this method of storage was based on reports

SAMPLE	DATE	WEIGH BILL NUMBER	TRAY NO.	TRAY WEIGHT	TRAY WEIGHT W/SAMPLE	TIME INTO OVEN	WEIGHT AFTER ( ) HOURS	WEIGHT AFTER ( ) HOURS	MOISTURE CONTENT
1									
2									
1									
2									
1									
2									
1									
2									
1									
2									
1									
2									

FIG. 3

of storage methods used by the pulp and paper industry and by one other large chip fuel user in the U.S.A.[1]

The major concerns relating to storage were:

a) moisture content of the fuel;

b) the freezing of the wood chips under conditions of high moisture content; and

c) the inability of the hospital fuel handling system to cope with frozen blocks of chips.

Wood chip fuel was first produced during the late autumn of 1981. At that time it was expected that the furnace would come into service in January, 1982. There were delays and the furnace did not come into operation until May 8, 1982.

At the request of the owner's representative the wood chips to be used at the initial lighting of the furnace were to have a moisture content of about 25%. This specification was met by selecting wood which had been cut for pulp some two years earlier and had been thoroughly air dried. This wood was chipped at the hospital using a small mobile chipper and the chips were blown directly into the fuel silo. Chipping was carried out on the day prior to the furnace start-up to ensure that the chips would be dry. The fuel silo is open on the top and it was feared that inclement weather could delay the start-up if chips were produced a week or two in advance. (Later events proved that heavy rain on the open silo could have a significant influence on furnace operation.)

Following the start-up, wood chip fuel was obtained from a storage pile at Iris, P.E.I., and delivered to the fuel silo. This fuel had a moisture content in the 50 to 60% range depending upon where it was taken in the storage pile. An extract from an analysis sheet for this early period is shown in Figure 4.

Through the summer of 1982 the moisture content of the fuel remained high, indicating that fuel drying in the warm summer weather was not taking place as had been expected. This factor was of concern since it was thought that unless the moisture content could be reduced, the hand-

[1] Burlington Electric Co., Burlington, Vermont, U.S.A.

SAMPLE	DATE	WEIGH BILL NUMBER	TRAY NO.	TRAY WEIGHT	TRAY WEIGHT W/SAMPLE	TIME INTO OVEN	WEIGHT AFTER (12) HOURS	WEIGHT AFTER (24) HOURS	MOISTURE CONTENT
1									
2.		SAMPLE ONLY							
1									
2									
1	29 MAY	E	R5	1918 g	5635	1630	3458	34-19	59.5%
2	29 MAY	E	L5	1922 g	5603	1630	3411	3394	60 %
1									
2									
1									
2									
1									
2									

FIG. 4

ling of frozen chips would be a serious problem during the coming winter (1982/83). An interim report on the feasibility of constructing a fuel storage drying facility adjacent to the KCMH was prepared by IEA in the latter part of 1982. This report estimated that covered storage with wire mesh sides, an asphalt pad and having a capacity of about 600 green tonnes would cost about $50,000. It was calculated that 600 tons would be a sufficient quantity of fuel to meet the heating needs of the hospital during the most severe winter months or until access could be gained to the secondary sources of fuel. (The secondary sources would be either a renewed chipping operation or removal of wood chips from an outdoor pile).

Savings forecasted for this storage would result from:

a) lower moisture content; and

b) the elimination of one transportation task.

The proposal to build a covered wood fuel storage facility at the KCMH was rejected as being uneconomic. As an alternative, space was rented in an unused potato warehouse. The space rented had a useable volume of about 3300 cubic meters which is approximately equivalent to 950 tonnes. This warehouse was located 1.3 km from the KCMH.

In the autumn of 1982 an agreement was again made with J.O. Hornby Ltd. to produce wood chips for the 1982/83 season. Chips for winter use however, were to be stored indoors (the potato warehouse) and chips for spring and summer use were to be piled outdoors at the cutting site (Cambridge).

This method of providing chips from covered storage during the winter months worked extremely well. The chips were always accessible and the moisture content was in the range of 40/50%. A moisture content analysis record sheet for the week of 9-14, April is shown on the following page as Figure 5. It should be noted that the winter was mild with very little snow and a winter of heavy snow and low temperature might present difficulties which could not be identified in 1982/83.

6.2 Wood Chip Drying and Monitoring

A separate monitoring project was undertaken to assess the benefits of indoor versus outdoor storage. The project was specifically related to the wood chip fuel being provided to the Kings County Memorial Hospital. Experience from the winter of 1981/82, during which wood chips were

SAMPLE	1982 DATE	WEIGH BILL NUMBER	TRAY NO.	TRAY WEIGHT	TRAY WEIGHT W/SAMPLE	TIME INTO OVEN	WEIGHT AFTER ( ) HOURS	WEIGHT AFTER (24) HOURS	MOISTURE CONTENT
1	9 APR.	LD. 1	R1	1861 g.	2500g	1000		2248	39.4%
2									
1	9 APR.	LD. 3	R2	1876g	2500g.	1040		2242	41.3%
2									
1	9 APR	LD. 5	R3	1879g	2500g.	1115		2216	45.7%
2									
1	14 APR	LD 1	L1	1942g	2650g	1200		2330	45.2%
2									
1	14 APR	LD 3	L2	1820g	2650g	1200		2304	41.7%
2									
1	14 APR	LD 5	L3	1943g	2650g	1200		2364	40.4%
2									
	14 APR	LD 7	L4	1917g	2650g	1200		2350	40.9%

FIG. 5

prepared and stored outdoors in three large piles, revealed that the moisture content was excessively high and that the wood chips were unsuitable for burning in the hospital heating plant. As noted earlier, samples taken during the summer showed that little drying was taking place. It was therefore decided to try two other approaches to drying the wood chip fuel:

1) First, a gasoline motor driven blower was used to force air into an underpile ventilation system. The outdoor pile was conical and had been prepared directly on the ground. The top of the pile was fitted with a tarpaulin cap.
2) Second, an electrically driven blower was used to force air into an underpile ventilation system in a pile of wood chips in covered storage (an old potato warehouse).

Wood chip samples were taken at intervals from the piles and measured for moisture content.

In addition, tests done on wood chips made from "cold decked" wood stored at Brudenell and on the effect of exposure in the hospital unit storage bin are reported.

6.2.1 Preparatory Work: The first wood chip pile was produced and built in October 1982, at Cambridge, P.E.I. During the wood chipping exercise an underpile ventilation system was constructed using a section of 12 inch (305 mm) culvert and approximately 200 feet (61 m) of flexible 4 inch (100 mm) field tile, in three loops. This ventilation system was laid out on the ground with about 6 inches (150 mm) of wood chips being used as a bed. The plan was to use this system during the early part of 1983 and just prior to the removal of the wood chips for burning. A sketch of the underpile ventilation system is shown in Appendix E.

An industrial blower was obtained, mounted on a trailer and prepared for use. The motor was a 4 cylinder Ford of approximately 20 shaft horsepower.

Thermometers were obtained and fitted with extensions in order to reach the required depth in the chip pile.

6.2.2 Information Collection: The services of Atlantic Energy Services were utilized to collect information on the changing status of the wood chip piles as the season progressed.

Atlantic Energy Services undertook a sampling/monitoring program during the period from November 1982 to June 1983. Copies of the monthly reports submitted are included in Appendix F.

6.2.3 Wood Chip Quantities: An outdoor wood chip pile at Cambridge was produced and built in October, 1982. The dimensions of the pile were:

Average height = 23' (7.0 m)

Base circumference = 208' (63.4 m)

Volume = 26,395 ft^3 (747.4 m^3)

This volume of 26,395 ft^3 (747.4 m^3) assuming a density of 18 lbs/ft^3 (288.3 kg/m^3), contained a mass of 238 green tons (215 green tonnes).

Photographs of this pile are included in Appendix G.

An indoor wood chip pile at Langley was produced and stored in November/December of 1982. The pile covered approximately 10,000 square feet (930 square metres) to a depth of 10 feet (3 metres) and contained approximately 1000 green tons (910 green tonnes) of wood chips.

Storage was in an unused potato warehouse which had an underfloor aeration system already in place. A sketch of the underfloor system is shown in Appendix H. The air is provided by a shrouded fan powered by a 20 HP electric motor. A photograph of the fan is included in Appendix H.

6.2.4 Moisture Content: The wood harvested for the wood chip fuel was a mix of small poplar, white birch, maple, spruce and fir. The moisture content varied slightly depending on where and when the sample was taken.

The samples taken during wood chip production at Cambridge on 25 October 1982 had moisture levels as follows:

Sample #1 44.4% Moisture Content

Sample #2 42.4% Moisture Content

Sample #3 33.8% Moisture Content

Moisture content levels on wood chip fuel delivered from the chipper to the hospital in the period December 1982/July 1983 are indicative of the moisture content levels in the Langley warehouse:

	M.C. % (Average)
December	48.8
January	47.4
February	48.1
March	46.6
April	43.2
May	43.6
June	37.9 to June 17

On the 17th of June chipping started on cold decked material at Brudenell. These wood chips were moved to the hospital silo as required and the remainder were stored in the Langley warehouse. The moisture content of these wood chips was found to be:

June 17/30 41.3%

July 33.1%

Additional details on this cold decking operation are given in Section 8.

During the month of March 1983, wood chip samples were extracted from the auger carrying the fuel to the furnace. The purpose of this exercise was to determine how much moisture was being added to the chips while they were resident in the hospital fuel silo. The results follow:

	M.C.% as delivered		M.C.% from feed auger
February 26	46.60	Mar. 2/4	48.4
Mar. 1/7	47.04	Mar. 6/10	50.2
Mar. 8/12	45.06	Mar. 10/16	47.25
Mar. 12/17	45.05	Mar. 16/20	46.6
Average for Month of March	46.5%		48.11%

During January, 1983, samples from the Cambridge outdoor pile were collected and were found to have a moisture content of approximately 50%. This indicated that the moisture content of the outer shell of the pile had increased during the winter.

6.2.5 Wood Chip Storage Temperatures: A temperature rise was noted in both the Langley and Cambridge piles shortly after completion of chipping. However, the rise was normal and at no time did the temperature exceed safe limits.

In December the temperature in Langley storage rose to 29°C and was reduced to 21°C by aerating. The Cambridge pile temperature rose to 55°C.

In January, Langley reached a high of 60°C while the Cambridge pile appeared to decline steadily to 18°C. During the remainder of the monitoring period there were localized warm spots in the piles but a general slow cooling was evident.

6.2.6 Results: The aeration of the wood chips in the Langley storage did little to reduce the moisture content. The electric blower which was powered by a 20 hp motor was operated for a total of 478 hours. If an electrical consumption figure of 18 kW.h/hour is assumed then the total electrical consumption during the exercise was 18 x 478 = 8604 kW.h. At a marginal commercial rate of $0.105/kW.h the aeration cost amounted to $900.00.

With one thousand tons of wood chips in storage the added cost of aeration was approximately $1/ton. The amount of drying was not measurable.

The aeration of the Cambridge outdoor pile took place over a two week period for a total of 113 hours in warm dry weather. Wood chip samples taken before and after provided little evidence that aeration is an effective or efficient means of reducing the moisture content of the wood chip fuel. During the 113 hours of aeration 15 tonnes of chips in the outer shell were dried from the high 60% region to the 30% region. A more detailed report is contained in Appendix F.

Aeration of the Cambridge pile cost $1869 for fuel, labour and travel. Assuming a wood chip pile of approximately 216 tonnes, this amounts to an expenditure of $8.65/tonne of wood fuel in the pile. Copies of interim reports on the project are contained in Appendix I.

6.2.7 Conclusions: The conclusions from the experiences reported above are:

1. Aeration of an outdoor wood chip pile while probably acceptable under certain circumstances is currently too expensive to warrant its use.
2. Wood chips in covered storage are relatively stable when pile depth does not exceed three metres and heating does not appear excessive.
3. Drying in storage over this short period was not readily apparent.
4. The reason for the poor drying performance is felt to be lack of adequate ventilation paths within the chip piles.

6.2.8 Recommendations: The following recommendations are expected to provide fuel of acceptable quality at reasonable cost:

1. The cold decking method of fuel storage appears to be the most appropriate means of providing:
   a) wood chip fuel having a moisture content level completely acceptable to the KCMH heating unit.
   b) the minimum number of fuel handlings between the wood lot and the heating unit.
2. Consideration should be given to the retention of some amount of covered storage to act as a buffer:
   a) in the event of a protracted period of adverse weather;
   b) to provide a more economical chipping operation; and,
   c) in the event of equipment failure.
3. Consideration should be given to the use of expendable plastic field tile within covered storage piles in order to provide natural ventilation and pile cooling.

7.0 WOOD CHIP FUEL DELIVERY

The fuel contractor (J.O. Hornby Ltd.) entered into a sub-contract agreement with a local trucking firm (Mr. Everett King) for delivery of wood chips to the hospital. The sub-contractor stated that no major difficulties were encountered during the winter of 1982/83. The fuel level at the hospital silo was checked every second or third evening, (personal visit) depending upon weather conditions and the sub-contractor's work schedule.

As noted earlier wood chips for winter use were in covered storage in an unused potato warehouse located 1.3 km from the fuel silo at the hospital. A front end loader was used to load the transport trucks at the wood chip storage site. The chips were then transported to the hospital where they were dumped onto a grate over the fuel silo. Following the filling of the silo a load or two of chips were frequently left piled on top of the silo grate and these would later be raked or "tickled" through the grate after the level of fuel in the silo had receded a sufficient distance to provide space. The mesh size of the grate is 38 cm x 13 cm.

The trucks are capable of carrying from 4 to 10 tons of chips, depending on the moisture content, species and chip size. A normal delivery quantity would be between 4 and 6 tons.

Wood chips were transported without cover and it was found that little or no spillage occurred because of this. The 1.3 km trip was through a fully built up area and seldom did the truck speed exceed 35 km/h therefore wind effect on the load was minimal.

Chip spillage did occur on two early occasions but this was the result of an improperly locked tail gate. In both cases the gate had been opened to permit rain water to drain out before loading. Complaints were received from the town on both occasions.

A short evaluation of the transport exercise was carried out during the spring of 1983 and the results are shown on the following pages.

Load No. 1

Start Time: 1335 h, May 27, 1983

Weather: Sunny

Temperature: 14°C

Quantity: Wood fuel was loaded into the box of a 10 ton truck. One side of the box had been raised to increase capacity. The top of the load was flattened and the load measured. As closely as could be measured the quantity of wood chip fuel in the box was: 490 ft^3 (13.8 m^3)

Gross Weight: 28100 lb (12746 kg)

Fuel Weight: 8000 lb (3628.8 kg)

Weight per Unit of Volume: 16.3 lb/ft^3 (262.0 kg/m^3)

Moisture Content: 39.8%

Distance Travelled: 1.3 km (one way)

Finish Time: 1410 h

Elapsed Time: 35 minutes

NOTE: Some difficulty was encountered with equipment operation which delayed the exercise by approximately 10 minutes.

Load No. 2

Start Time: 1410 h, May 27, 1983

Weather: Sunny

Temperature: 14°C

Quantity: See notes on load No. 1. As closely as could be measured the quantity was: 510 ft^3, (14.4 m^3)

Gross Weight: 28400 lbs. (12882 kg)

Fuel Weight: 8300 lbs. (3764.8 kg)

Weight per Unit per Volume: 16.3 lb/ft^3 (262.0 kg/m^3)

Moisture Content: 41%

Distance Travelled: 1.3 km (one way)

Finish Time: 1435 h

Elapsed Time: 25 minutes

Load No. 3

Start Time: 1435 h

Weather: Sunny

Temperature: 14°C

Quantity: See notes on load No. 1. As closely as could be measured the quantity was: 500 ft^3, (14.2 m^3).

Gross Weight: 28200 lb (12791 kg)

Fuel Weight: 8100 lb (3674.2 kg)

Weight per Unit of Volume: 16.2 lb/ft^3 (259 kg/m^3)

Moisture Content: 38.8%

Distance Travelled: 1.3 km (one way)

Finish Time: 1458 h

Elapsed Time: 23 minutes

8.0 WOOD FUEL HARVESTING PROCESS

An independent evaluation of the wood harvesting was undertaken by Mr. George Mason, BSC (Forestry), MBA, on behalf of IEA Consulting Group. Mr. Mason's report is contained in the following paragraphs.

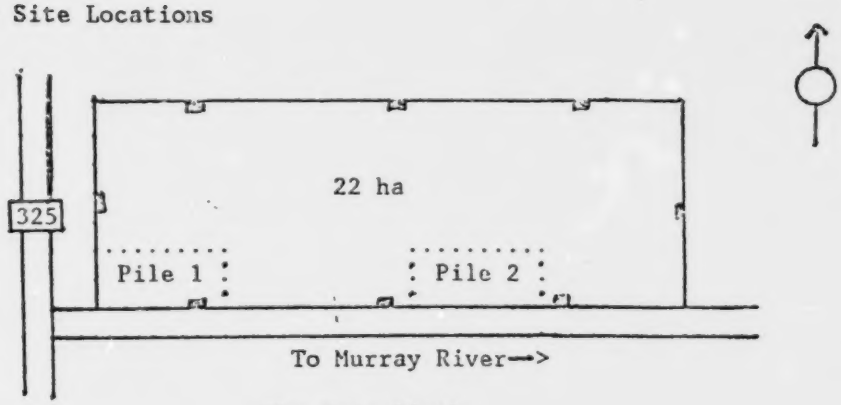
8.1 Wood Fuel Production

Wood chip fuel for the project was produced from three major harvest operations: the Iris block, the Cambridge block (2 harvest sites) and the Brudenell block. The general locations and configurations of these blocks are outlined in Exhibit 1. Each block was evaluated separately.

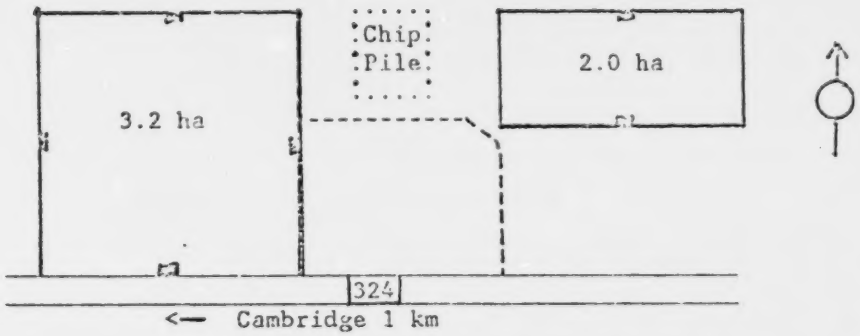
8.1.1 The Iris Block: The harvest block was 8.9 ha (22 acres) and had a cruise volume of 1263.8 cubic meters (523.6 cords) of merchantable wood. Harvesting took place during November and December, 1981 and produced 159.1 cubic metres (66 cords) of sawlogs and approximately 1814

Exhibit 1

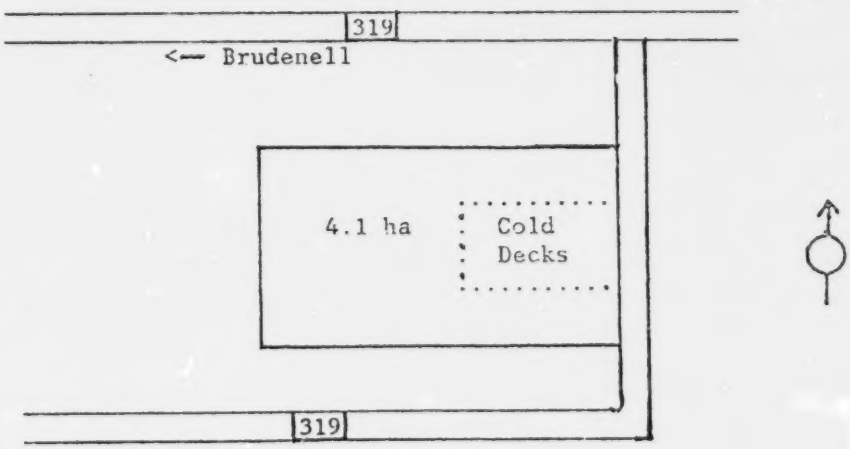
Harvest Site Locations



The Iris Block



The Cambridge Block



The Brudenell Block

tonnes (2000 tons) of chips (approximately equivalent to 2410 cubic metres (1000 cords) of green wood). The biomass volume was approximately double the merchantable volume. This observation is consistent with the results presented by Wilton and Duffet (1980) and Pratt (1978).

The harvest operation employed 2 cutters with chainsaws, a grapple skidder which forwarded logs, a truck mounted grapple boom which loaded the chipper, and a chipper which blew chips into piles at roadside. Chipper utilization could have been increased by at least 30% if it had been fed faster. A possible alternative would have been to use 3 cutters and two grapple skidders.

There were initial problems with the chipper letting large pieces, branches and bark through which could clog the boiler feed at the hospital. The chipper was improved by welding extensions onto the chipping anvil and no major problems have occurred since the modification.

When needed, chips were loaded at the site by front end loader and transported to the hospital and to the Lower Montague storage pile by covered dump truck. Where chips were being shipped directly to the silo at the hospital or to storage, an extra loading by front end loader was involved. Where chipper position permitted it, double handling could have been avoided by coordinating the trucks so that chips were blown directly into waiting transports.

8.1.2 The Cambridge Block: The harvest block was divided into an eastern block of 3.2 ha (8 acres) and a western block of 2.0 ha (5 acres). An independent cruise was not completed on this site prior to cutting. Harvesting took place during October and November, 1982 and produced 145 cubic metres (60 cords) of logs and 891 tonnes (982 tons) of wood chips. An additional 608 tonnes (670 tons) were harvested from the St. Mary's Road block during December, 1982.

The harvesting operation used 2 cutters with chainsaws (440 tonnes) and a feller buncher (1055 tonnes). Full trees were transported using a grapple skidder and chipped into a conical pile (225 tonnes) and into covered dump trucks for transport to the hospital (96 tonnes) and the Langley Warehouse (976 tonnes). Chipping directly into dump trucks eliminated one unnecessary loading. The evaluation of the conical pile for predrying was reported above.

8.1.3 The Brudenell Block: The Brudenell block was 4.1 ha (10 acres) and had cruise volumes of 305.9 cubic metres (126.9 cords) of merchantable wood and 545 tonnes (600 tons) of biomass. The block was harvested in January, 1982 and cold decked (full trees piled near the road without further processing) on site. Harvest volume had not been determined at the time of this report.

The operation employed a feller buncher and grapple skidder for forwarding and piling the trees into cold decks. The intention is to chip the piles on demand into dump trucks and haul the chips directly to the hospital silo or to intermediate storage.

Cold decking offers a number of potential advantages. The cut and skid operation can work at capacity. The cold decked wood will drop most of its high nutrient foliage on the site before being chipped and will undergo a substantial amount of drying because of the excellent air circulation through the piles. Experience with the cold decked material showed that the moisture content was as low as the high 20's. Even lower moisture may be possible if the material is left longer. Wilton and Duffet (1980) reported moisture contents as low as 16% (of wet wood) for chips from fire killed timber. Cold decked wood has the minimum value added at storage of the three methods which results in the lowest inventory carrying costs. The cold decked wood can also be chipped directly into dump trucks and hauled to the hospital silo with no intermediate loading costs. An evaluation of the tradeoff between chipper setups, inventory savings and intermediate loading is given in Exhibit 2. The analysis indicates that cold-deck storage has significantly lower cost than warehouse storage or conical-pile storage.

8.2 Fuelwood Harvesting Practices

The fuelwood sites were all clearcut using the full tree method with all stems of significant size removed from the site. Wood that was dead and rotten was generally left on the site because it was not suitable for fuelwood. Each site was evaluated individually.

8.2.1 The Iris Block: The stand harvested was predominantly small poplar, white birch and maple of fuelwood size with approximately 18 cubic metres/ha (3 cords/ acre) of spruce-fir sawlogs. The sawlog volume would not normally justify harvesting the block.

Exhibit 2

Comparison of Fuel Production Methods

Costs derived from most recent hospital charges and from adjusted data from New Hampshire (Damman and Andrews, 1979) and Newfoundland (Wilton and Duffet, 1980).

Cost per 1800 green tonnes (1 year fuel supply)[1]

Operation	Process 1 Langley Storage	Process 2 Chip-pile Storage	Process 3 Cold Deck Storage
Cut & Skid	$21,780	$21,780	$21,780[2] ---Inventory---
Chipping	$14,184	$14,184 ---Inventory---	$14,184
Haul to Storage	$6,534 ---Inventory---	---	---
Delivery (15 km)	$13,068	$13,068	$9,144[3]
Inventory Cost (@ 10% for 6 mos.)	$2,125	$1,798	$1,089
Additional[4] Chipper Setups	---	---	$2,500
Total Cost	$57,691 $32.05/tonne	$50,830 $28.24/tonne	$48,697 $27.05/tonne

[1]Assumes no charge for warehouse storage. Warehouse storage is assumed to be a short term expedient. See Section 6 for a discussion of wood chip preparation and handling.

[2]Although extra equipment was used to stack the material in the cold decking operation, the stacking could be done by the skidders in a full-time operation and the extra cost would be minimal. For this trial the extra cost is estimated at $2/green tonne but has not been included since these results are intended to portray long term costs.

[3]Blowing chips into trucks avoids intermediate loading.

[4]Based on 10 setups, each taking 5 hours and costing $50/h for vehicles and labour.

The clearcut operation removed all stems and left virtually no slash on the harvest block. Mineral soil exposure on the site was excellent and no more than 2 cm (3/4 in.) of duff or litter was present. The site was planted in the spring of 1982 with no preparation other than harvest. Survival to date is excellent; however, aspen competition is likely to be a problem in the near future.

The chip piles eliminated planting from approximately 0.45 ha (1.1 acres) of the site. Where the piles had already been moved, there was a covering of wood chips on the ground which killed virtually all of the container stock planted in those areas. While the area could be improved by raking away the chips prior to planting or waiting until the chips have deteriorated, the most effective action would be to minimize the area occupied by the chip piles.

8.2.2 The Cambridge Block: The harvest stand was predominantly small poplar, white birch and maple of fuelwood size with some spruce, white pine and fir sawlogs. An estimated 3.6 tonnes (4 tons) of slash with wood fuel potential was left on the western block. While the amount of wasted wood was small, removal would have improved the yield from the block and made planting easier. The eastern part of the site had negligible slash accumulation and no more than 4 cm (1.6 in.) of duff or litter. The entire site should be ready for planting without further treatment.

8.2.3 St. Mary's Road Block: The St. Mary's Road block may require some disking to remove small residuals before planting. The residuals were too small to be harvested efficiently by the feller buncher and were therefore left standing.

8.2.4 The Brudenell Block: The harvest was predominantly spruce, fir and poplar of fuelwood and marginal studwood size. The entire block was clearcut and piled near roadside. Approximately 20 spruce-fir logs of 15-25 cm (6-10 in.) were piled for chipping. While the quality of these logs was difficult to evaluate in the piles, approximately half of those observed were suitable for studwood or sawlogs. This amounts to approximately 6 cubic metres (1 cord) of wood that should be processed for lumber; however, separation of such a small volume could not normally be justified economically.

The high water table on the southwest corner of the block will make planting difficult; however, this would have resulted from any harvesting operation on the site. Some soil disturbance was also observed in the above area which was attributed to using the feller buncher on the wet site before it was completely frozen. The remainder of the site had negligible slash, less than 4 cm (1.6 in.) of duff and should be ready for planting without further treatment.

8.3 Evaluation

A full evaluation must consider the impact of the operation on the forest resource, the costs of alternate treatments and the benefits to the economy.

The hospital uses approximately 1800 tonnes of wood chip fuel per year which has been harvested from approximately 8.1 ha (20 acres) of forest land. Assuming a 30 year rotation for the fuelwood forest and the present average biomass harvest of 225 tonnes/ha (100 tons/acre), the operation will require a woodlot of approximately 245 ha (600 acres) for sustained yield. The growth of the second rotation will be dependent on the species used, the level of management and the forest site. At present, the operation results in the clearing of low quality forest that would not otherwise be harvested but can now be reforested with a commercial forest crop. In the future, wood fuel could be generated from forest thinnings which could make the treatment economical and greatly improve the quality of the Island's forests.

The full tree harvesting operation removes virtually all of the forest crop from the area and prepares the site for planting with virtually no further treatment. To assess the benefits of this method, a conventional operation which leaves the branches, tops and unmerchantable wood could require $150/ha ($60/acre) for clearing, piling and burning brush and $300/ha ($120/acre) for disking the site before planting. These costs would be borne by the Provincial Government and added to the cost of reforesting the harvest block. The chipping operation leaves the site ready for planting without further treatment which could save the Government up to $445/ha ($180/acre) in reforestation costs. The real saving is probably closer to the $150/ha clearing cost which produces much the same result as the full tree operation. This saving is a real benefit

generated by the full tree harvesting operation and should be credited to it. The benefit would be comparable to a cost reduction of approximately $1.20/tonne.

Given present production, the harvest operation generates approximately 12 mandays of employment per 100 tonnes of chips of 220 mandays per year. The planting operation should create an additional 20 mandays of employment each year. The chip supply operation therefore generates directly approximately 1 man year of employment. While this is not a large benefit, the conversion of a dozen or so facilities could have a significant impact on local employment. Much of the work could also be carried out in the winter months when employment is seasonally low.

8.4 Recommendations

The following practices and procedures are recommended for the wood chip harvesting operations:

1. Harvesting should be carried out using the cut, skid and cold deck method used on the Brudenell block. Cold decked wood would be chipped and shipped to the hospital or storage on demand. Exhibit 2 illustrates the potential saving that would result from using this method.
2. Further analysis should be conducted to verify the cost figures in Exhibit 2, to compare the moisture contents of the cold deck chips and to evaluate alternative methods of chip supply. Two promising alternatives are increasing the storage capacity at the hospital and establishing a centralized chipping facility once chip supply has expanded to a full time operation.
3. Manual felling should be preferred wherever feasible. The feller buncher operations left a number of small residuals and created significant disturbance on wet sites.
4. The $150/ha site preparation saving that results from the full tree harvesting operation should be credited to the fuel supply operation. This could be accomplished through either a reduction in the stumpage fee or a refund to be granted once the harvest is complete and the area determined to be adequately prepared for reforestation.

8.5 References

Beale, B., E. Haites and P. Love. 1980. An assessment of the economic impacts of a wood fuel industry in P.E.I. Prep. for the Institute of Man and Resources by Middleton Associates, Toronto.

Damman, J.C. and R.A. Andrews. 1979. Economics in fuel wood supply firms in New Hampshire. Research Report No. 76, New Hampshire Agr. Exp. Station, Durham, NH. 23 pp.

Wilton, W.C. and W.P. Duffet. 1980. Whole tree chipping for logged fuel in Newfoundland. ENFOR project P-115, Canadian Forestry Service, Ottawa. 55 pp.

Pratt, Martha (Ed.). 1978. Whole tree harvesting in P.E.I. The Institute of Man and Resources, Charlottetown, P.E.I. 12 pp.

9.0 SYSTEM MAINTENANCE

9.1 General

The operation/maintenance of the heating plant is undertaken on a three shift basis by four (4) full time stationary engineers and one (1) part time engineer. The heating plant staff is supervised by a chief stationary engineer.

During a shift, operators are required to perform all boiler room tasks and to complete a boiler room report. A copy of the report form is shown in Figure 6. The tasks undertaken in regard to the wood furnace/boiler are described in the following sub-sections.

9.2 De-Ashing

De-ashing is undertaken during every evening shift and ash slicing is performed two or three times per shift. It was found from experience that ash slicing prevents the formation of large clinkers and makes the de-ashing task easier.

9.3 Twigs and Oversize Chips

The fuel transport system is monitored as frequently as possible. Long sticks, twigs and oversize chips are collected as they appear on the face of the fuel pile under the bridge wall and before they drop into the first auger. The quantity of material gathered varied from week to week with the largest amount being approximately 0.25 m^3 gathered in one day.

KING'S COUNTY MEMORIAL HOSPITAL
Montague, P.E.I.

B O I L E R R O O M

SHIFT	DATE
BOILER BLOWDOWN	TIME
CIRCULATING PUMP #1	#2 1
BOILER OPERATING #1	#2 1
BOILER P.S.I.G. #1	#2
AIR COMPRESSOR DRAINED # 1	#2
ROUNDS OF HOSPITAL - TIME	
EXHAUST FANS, TIME OFF #	TIME ON #
MAIN DOOR - TIME LOCKED	TIME OPENED
LAUNDRY STEAM: ON	OFF
BOILER OIL FUEL	FUEL METER READING
WATER SOFTENER TEST	O.K. NIL
OXYGEN READING: L. BANK	R. BANK

MAINTENANCE REPAIRS:

REMARKS:

OPERATOR

FIG. 6

This material is manually fed into the fuel cell. Virtually no material was being gathered during April 1983.

9.4 Lubrication

Lubrication of augers, motors, drives, etc. is performed weekly.

9.5 Stack Drain

Condensation is drained from the stack on a weekly basis (involves opening and closing a valve). The quantity of liquid removed depends on the moisture content of the fuel and the time elapsed since the last boiler tube cleaning. A large amount of liquid condenses out immediately following a boiler tube cleaning.

9.6 Boiler Tube Cleaning

Boiler tube cleaning is carried out every four months or when the stack temperature exceeds 700°F (371°C). Stack temperature normally drops about 200°F (93°C) following a cleaning.

9.7 Hydraulic Scraper System

The hydraulic pump which powers the scraper system requires periodic filter changes and continuous checking for leaks or ruptures. The record of boiler room activity shows that this item demands a high level of unscheduled maintenance.

9.8 Induced Draft Fan

The blades of the induced draft fan must be cleaned at least once every two weeks.

10.0 SYSTEM PERFORMANCE - OPERATIONAL

10.1 General

The system is relatively unsophisticated when measured against liquid fuel furnaces but does require continuous monitoring in order to eliminate stoppages caused by unacceptable or oversize items in the fuel.

Operators state that they like the system, that it is easy to operate and that it has not presented any major operational problems.

10.2 Incident Report

An incident report summary and related boiler room reports are included in Appendices J and K.

It can be seen that the majority of these items are minor in nature. The blowbacks[1] which occurred on 27 and 28 November 1982, were potentially serious. In this case it was found that the problem could be corrected by adding overfire air whenever de-ashing is in progress, and by running the induced draft fan thus keeping the fuel cell under negative pressure.

The greatest nuisance item is the jamming of the inclined auger. Some 18 separate incidents were recorded. Following the addition of rakes on the end of the auger shaft the incidence of jams was reduced. Before the change, 14 jams occurred in five months: afterwards only four occurred in seven months. Chip quality also improved and this may have contributed to the reduction.

One incident which was not recorded since it occurred under test conditions in July, was a shut down caused by flooding. A very severe rain storm resulted in large amounts of water being introduced into the open fuel silo and on top of the chips. Some loose material and chips were carried along by the water to the drain and the drain became clogged. The first indication of a problem was a slowly dropping steam output coupled with the continuous running of the furnace stoker system.

Because of the clogged drain, saturated chips and water were being carried directly into the combustion chamber and the fire was slowly dying. The operator shut down the system, cleared the drain and brought the back-up oil boiler into service.

After about four hours the residual heat in the fuel cell refractory had driven off the excess moisture and the system was restarted. A re-light was not required.

In order to prevent a recurrence, an improved screen was installed at the entrance to the drain.

---

[1] A "blowback" is a low grade explosion which usually results when air (oxygen) is added to a build-up of unburned gases in an oxygen deficient atmosphere with an ignition source present.

10.3 Reliability

The system can be described as being extremely reliable, however, there are a number of small items which must be watched continuously in order to avoid a shut-down. Some of these are described below:

10.3.1 Auger Jamming: These jams are a nuisance and require the opening of the inclined auger tube for clearance. The jams are caused by oversize chips, twigs or branches which pass through unnoticed and subsequently lodge in the inclined auger. The clearing time is approximately 30 minutes depending upon type and location. The extracts from the boiler room report include every auger jamming incident reported.

10.3.2 Overfire/Underfire Fans: The fuses on these two systems are marginal. During the start-up period they failed frequently. By moving some wires and installing a fan in the control panel the problem seems to have been corrected. The panel is exposed to radiant heating from the boiler and this probably contributed to the problem.

10.3.3 Twigs and Branches: This item was mentioned under maintenance as requiring continuous checking. Regardless of the monitoring, shut downs do occur. One failure occurred while the writer was observing the aeration and the cause was not apparent until a detailed scan of the system was carried out to find the offending twig. In this case a twig about 375 mm long emerged from the wood chip pile and the point pressed directly into one of the hydraulic pump shut down paddles. This twig was less than 15 mm in diameter.

10.3.4 Major Failures: Major failures were rare and amounted to one 11 day shut down in the course of the year. On the 24 of September 1982 induced draft fan lost one blade and the system had to be shut down. An examination revealed a defective weld as being the cause of the failure. A new induced draft fan was provided under warranty by the manufacturer.

10.3.5 System Back-up: In the early stages it was assumed that an oil boiler should always be kept on "stand by" during the winter months since historically one oil boiler had always been kept on "stand by". This was found to be unnecessary with the wood fired system and additional oil savings were accomplished as a consequence.

In the wood fired system there is a large mass of refractory in the fuel cell which contains a very large amount of heat. In the event of a power failure this heat continues to be given off to the boiler and there

is a sufficient amount available to permit the continued provision of steam to the hospital for periods of up to two or three hours depending upon demand.

An oil boiler requires only 50 minutes in which it may be fired up from a cold start and brought up to operating pressure.

11.0 TECHNICAL EVALUATION

In the period 14 July to 30 August 1982, Crowfield Associates of Crapaud, P.E.I., under subcontract to IEA Consulting Group, carried out a series of tests for the purpose of determining the technical performance of the KCMH heating plant. A full copy of the Crowfield Report is included as Appendix L to this report.

The efficiency claimed by the manufacturer[1] for the furnace is:

"efficiency 75% (equated to net heat value of fuel as fired)"

This statement does not provide an adequate indication of whether the higher or lower heating value of fuel was used and as a result Crowfield Associates proceeded with their evaluation on the basis of the higher heating value. In a later conversation with the Canadian manufacturer it was learned that "net heat value" refers to the manufacturers interpretation of the lower heating value. As a consequence the efficiencies determined by test were lower than those quoted by the manufacturers.

In summary:

a) An accurate measurement of fuel consumption was obtained by manually loading the wood chips into metal containers, weighing each filled container on platform scales, recording the data and then dumping the wood chips in the fuel feeding system. Fuel samples were also collected on a regular basis for analysis.

b) The maximum output achieved was 1380 kg/h at 524 kPa (76 psig) representing a thermal output of 3.46 GJ/h (3.28 MBtu/h)[2] for a period of 12 hours. This output exceeds the maximum output stated by the equipment manufacturer. Steam flow was measured using an EMCO turbine steam meter having an accuracy of 1%.

---

[1] A copy of the manufacturers specification is included as Appendix A.

[2] The manufacturer declared an output of 3.146×10^6 Btu/hr.

c) The unit normally operates with little or no visible smoke, however short bursts of heavy black smoke occur during "off" periods when the system is operating on medium to high loads and particularly with dry fuel. A smoke number exceeding 9 on the Bacharach smoke spot scale was recorded.

d) The boiler feedwater input temperature varied during the technical evaluation between 36°C and 60°C. There is a significant difference between these temperatures and the 100°C temperature recommended by the equipment manufacturer.

The following table shows furnace efficiency based on both the higher and lower heating values for fuel.

Comparison of Efficiencies at the Kings County Memorial Hospital Wood Fuel Boiler Based on Both Higher and Lower Heating Values

Test Load	Fuel Moisture	Efficiency	
% of maximum	% (wet basis)	% - Higher Heating Value[1]	% - Lower Heating Value[2]
50	66	55.3	80.0
50	52	64.9	81.4
50	26	57.8	65.1
100	26	66.1	75.4
Average:		61.0	75.3

[1]From table on page 6 of Crowfield Associates report.

[2]From a letter of transmittal to the P.E.I. Energy Corporation from Resource Ventures Incorporated dated June 15, 1983.

12.0 ELECTRICAL CONSUMPTION

In the initial review of the Anga & Varme specification for the wood chip furnace it was noted that a number of electrical motors would be installed to provide power for the furnace and associated equipment. The horsepower rating of these motors is as follows:

	H.P.	(Watts)
Induced draft fan	5.0	(3730)
Air fans	1.0	(746)
Ash removal auger	2.0	(1492)
Ash transport auger	2.0	(1492)
Hydraulic pump	7.5	(5595)
Fuel, cross auger	3.0	(2238)
Fuel, inclined auger	3.0	(2238)
Fuel, stoker auger	5.0	(3730)
Fly ash collector valve	0.75	(560)

The electrical power rate on P.E.I. is high and amounts to a marginal rate of about 10.5 cents per kW.h for commercial users. The quantity of electrical energy consumed by these motors would be significant if they were to operate on a full time basis and some concern was expressed regarding electrical operating costs. (In fact, electrical energy consumption proved to be somewhat lower than anticipated.)

A watt-hour meter was installed to measure the energy supplied to the A & V furnace. The meter began recording during the first week of July 1982 and a reading taken on May 12, 1983 showed a total of 23,520 kW.h consumed over the ten month period. The watt-hour meter does not measure the electrical energy consumed by the 500 watt lighting load in the new boiler room nor does it measure the electrical energy consumed by the drying oven used in the moisture content analysis of the fuel.

The hospital records show that electrical energy consumption increased by 33,200 kW.h for the ten month period July - April 1982/83 when compared with the same ten month period of 1981/82. No other hospital practice or equipment installation other than the wood boiler has been identified to account for the increase. On a monthly basis this would amount to an average increase in consumption of 3,320 kW.h. Over the same period the watt-hour meter recorded an average monthly electrical energy consumption for the furnace of 2,352 kW.h.

The fuel sample drying oven which is used for fuel moisture content analysis has a 3 kW rating. During periods of high fuel usage the oven is in almost continuous operation. In the summer months usage drops off to approximately 48 hours/week (one test).

Maximum possible usage/month = 2160 kW.h

Minimum usage/month = 575 kW.h

The estimated monthly electrical consumption = 1500 kW.h

The lighting load is more difficult to estimate. Hospital staff members are energy conservation conscious and lights are turned off whenever possible. When the new boiler room came into operation the lighting in the old boiler room was reduced to essential lights only. For purposes of this analysis it was assumed that the 500 watt lighting load was in use 10% of the time.

0.5 x 24 x 30 x 10% = 36 kW.h/month

The oil boilers have been estimated to have had a 30% load factor prior to the installation of the wood burner. This leads to an estimate of electrical power usage of approximately 1000 kW.h per month in the past. As a result of the oil boiler shut down this amount of electrical energy has been saved.

Summary

Average monthly increase (over 10 month period) according to KCMH records.	+3,320
Contribution as a result of oil burner shut down.	+1,000
Average monthly usage (over 10 month period) recorded for the wood burning furnace (metered).	-2,352
Average monthly usage for the drying oven (estimated).	-1,500
Lighting load per month (estimated).	- 36
Unaccounted for	432 kW.h/month

At a marginal rate of 10 cents/kW.h this means that approximately $43.20 is unaccounted for in a monthly electrical bill for the boiler room of $332.00. (It is possible that the lighting load estimate is erroneous which would account for the 13% error.) The use of the drying oven was eliminated recently when testing showed that the wood chip samples could be dried by placing them on top of the combustion chamber. This would reduce the extra electricity cost to about $182/mo.

13.0 KCHH - ECONOMIC EVALUATION

13.1 Objectives

The objectives of the economic evaluation were to:

(i) compare the costs of operation for the oil fueled system with the wood fueled system, after necessary adjustments for the number of degree-days in the period;

(ii) assess the labour impact, particularly employment generation, in the local area;

(iii) assess the impact upon the forest industry;

(iv) prepare calculations of simple payback, net present value and internal rate of return for the investment in the wood chip boiler; and

(v) assess the amount of fuel oil displaced by the system.

13.2 Methodology

13.2.1 Operating Costs: The costs of operation when using the oil burners were compared to the costs of operation when using the wood chip fueled system. Data for a complete year on each system if available would be used. The intention was to normalize these data using degree-day information and add in any extra costs associated with the wood chip system, such as the electrical costs for auger motors or fans, which would be charged to the wood system.

In order to normalize the heating data it is necessary to know the hot water load so that it can be deducted from the total fuel consumption. The amount remaining is that portion used for heating only and would vary according to the severity of the weather. Unfortunately, it was not possible to isolate the hot water consumption and the comparison between #2 fuel oil and wood chip fuel had to be on a general basis.

13.2.2 Labour Impact: The labour content in the production of chips was assessed using actual records of production costs provided by J.O. Hornby. A projection of annual chip consumption was then used to provide an estimate of the overall employment generation potential for the fuel supply operation.

13.2.3 Forest Industry Impact: An assessment is made of the impact upon the forest resource in another portion of this report. Key features

of this assessment can be used to project the impact upon the forest industry in the area of the Kings County Memorial Hospital.

13.2.4 Capital Budgeting Analysis: Standard capital budgeting procedures were used to assess the attractiveness of the investment. A time horizon of 20 years, the expected life of the investment, was used for the evaluation. Simple payback, net present value and internal rate of return were calculated.

13.2.5 Fuel Oil Displaced: An estimate of the amount of fuel oil displaced was made using both an analysis of the heating value of the wood chips consumed and an analysis of fuel oil consumption in past years.

13.3 Evaluation Results

13.3.1 Operating Costs: Fuel delivery figures for the two years immediately prior to the installation of the wood chip fuel system were obtained and are shown in Tables 13-1 and 13-2. As can be seen in Table 13-1, 413,058 litres were consumed over a 356 day period from early May 1980 to late April 1981. Over a similar 372 day period in 1981/82, as shown in Table 13-2, 371,162 litres were consumed.

No satisfactory explanation could be found for the difference in fuel consumption during the two periods. Because the fuel delivery amounts shown in Tables 13-1 and 13-2 indicate only the amount delivered and not the amount required to fill the tank (except in the instances noted), no comments can be made on the month to month consumption data. The normal procedure in cases such as this is to take the fuel consumption figures for July and August and use them to derive a value for fuel required to heat domestic hot water. (It is assumed that no heating takes place during these two months and therefore heating demand is for hot water and stand-by losses alone.) The fuel consumption for domestic hot water can then be extrapolated for a complete calendar year and deducted from the total annual consumption. The amount remaining would represent the fuel required solely for heating. This final value could then be adjusted according to the number of degree-days in the period and compared to other years.

Because it was not possible to estimate the fuel consumed to produce hot water, no degree-day adjustment could be made to the fuel consumption figures.

TABLE 13-1

Kings County Memorial Hospital
Record of Fuel Oil Delivery (1980/81)

Amount Delivered (litres)	Date	Amount Delivered (litres)	Date
	8 May 1980*	10728	Jan. 1981
10734	May 1980	10738	Jan. 1981
10761	May 1980	10570	Jan. 1981
10773	May 1980	10622	Jan. 1981
10738	May 1980	9632	Jan. 1981
9990	May 1980	10702	Jan. 1981
10738	July 1980	5169	Jan. 1981
10650	July 1980	10779	Feb. 1981
8775	Aug. 1980	10663	Feb. 1981
10786	Oct. 1980	10689	Feb. 1981
10696	Oct. 1980	10677	Feb. 1981
10762	Oct. 1980	10785	Feb. 1981
8650	Nov. 1980	10772	Mar. 1981
8705	Nov. 1980	10776	Mar. 1981
10759	Nov. 1980	10781	Mar. 1981
10778	Nov. 1980	10706	Apr. 1981
10708	Nov. 1980	10667	Apr. 1981
10713	Dec. 1980	10711	28 Apr. 1981*
10770	Dec. 1980		
10823	Dec. 1980		
10082	Dec. 1980	413,058	Total Consumption
8748	Dec. 1980		
10752	Dec. 1980		

Average Daily Consumption,
8 May 1980 to 28 April 1981

$$= \frac{413{,}058 \text{ litres}}{356 \text{ days}}$$

= 1,160.3 litres/day

*Tank completely filled.

TABLE 13-2

Kings County Memorial Hospital
Record of Fuel Oil Delivery (1981/82)

Amount Delivered (litres)	Date	Amount Delivered (litres)	Date
	28 Apr. 1981*	9806	Dec. 1981
10779	May 1981	5729	29 Dec. 1981*
10768	May 1981	3686	Jan. 1982
10772	May 1981	6032	Jan. 1982
7860	May 1981	8529	Jan. 1982
7748	July 1981	6886	Jan. 1982
6919	July 1981	8517	Jan. 1982
7663	July 1981	8561	Feb. 1982
8601	July 1981	6043	Feb. 1982
3794	July 1981	7266	Feb. 1982
5304	Aug. 1981	6120	Feb. 1982
8391	Sept. 1981	3177	Feb. 1982
8684	Sept. 1981	8410	Feb. 1982
8376	Oct. 1981	5489	Mar. 1982
8622	Oct. 1981	4620	Mar. 1982
11484	Oct. 1981	8730	Mar. 1982
4154	Oct. 1981	2922	Mar. 1982
2513	Nov. 1981	8385	Mar. 1982
8532	Nov. 1981	10577	Apr. 1982
8352	Nov. 1981	8768	Apr. 1982
5919	Nov. 1981	8523	Apr. 1982
8395	Nov. 1981	11412	Apr. 1982
1139	Nov. 1981	2033	May 1982
4632	Dec. 1981	11297	5 May 1982*
11508	Dec. 1981		
8404	Dec. 1981	371,162	Total Consumption
3150	Dec. 1981		
7181	Dec. 1981		

Average Daily Consumption,
28 April 1981 to 5 May 1982

$$= \frac{371{,}162 \text{ litres}}{372 \text{ days}}$$

= 997.7 litres/day

*Tank completely filled.

An approach that would permit a comparison of operating costs between wood and oil involves taking the known amount of wood chip fuel consumed and converting it to an equivalent amount of fuel oil. This is possible since both the moisture content of the fuel and the thermal efficiency of the boiler are known. Table 13-3 contains the calculations required for this conversion. An average thermal efficiency of 70% for the wood chip unit (based on test data included in Appendix L to this report) has been used in this conversion.[1] The result is an equivalent figure of 384,000 litres of fuel oil. To this must be added approximately 8,000 litres, the amount of oil consumed during the eleven day period in late September 1982 when the wood unit was out of service. This results in an overall figure of 392,000 litres of fuel oil for the 1982/83 period.

The equivalent fuel consumption figure (392,000 litres) is of the same order of magnitude as the figures for 1980/81 and 1981/82. Some conservation activity did take place prior to the winter of 1982/83 (extra windows were added and an air lock was constructed over the ambulance entrance) but no conclusions regarding the impact upon fuel consumption can be drawn. In addition, the period from May 1, 1981 to April 30, 1982 contained 4586 heating degree-days while the period from May 1, 1982 to April 30, 1983 contained only 4368 heating degree-days.

There is an increased electrical cost associated with the electrical motors on the wood unit. As noted elsewhere in this report a watt-hour meter was installed to monitor the increased electrical consumption. The average monthly increase in electrical consumption for the unit, the lights in the wood boiler room and the drying oven was found to be 3320 kW.h per month.

Since the staffing levels in the heating plant are the same for both oil and wood, with the exception of the allowance discussed in 13.3.4, the relevant operating costs to be examined in assessing the economic attrac-

[1] Although under ideal conditions the unit achieves thermal efficiencies in excess of 70%, the figure of 70% was used as a good value under normal operating conditions. The reduction would be due to an average load on the unit of about 40% of peak capacity whereas the measured results were at loads of 50% of peak and higher. Using a figure of less than 70% does not seem reasonable since the overall input/output efficiency was found to be between 66% and 68% (see page 45), and some of the losses would contribute to the building's heat demand.

TABLE 13-3

Conversion of Actual Wood Chip Fuel Deliveries to Equivalent Amount of Fuel Oil

Date	Amount (kg)	M.C. (%)	kJ/kg (LHV)	kJ (10^9)
May, June & July	411,000	57	6400	2.630
August	130,000	47	8550	1.112
September	81,800	51	7700	0.630
October	176,000	59	6000	1.056
November	156,000	48	8300	1.295
December	203,000	49	8100	1.644
January	244,000	47	8550	2.086
February	215,000	48	8300	1.785
March	224,000	46	8750	1.960
April	178,000	43	9400	1.673
Total	2,018,800	--	----	15.871

At average efficiency of 70% based upon the LHV, the available heat energy

$= .70 \times 15.871 \times 10^9$ kJ $= 11.11 \times 10^9$ kJ

At average efficiency of 78% based upon the LHV for oil, an oil burner would need gross heat

$= 11.11 \times 10^9$ kJ/.78 $= 14.24 \times 10^9$ kJ

At a lower heat value of 37,100 kJ/litre for #2 fuel oil, this is equivalent to an amount

$$= 14.24 \times 10^9 \text{ kJ} \times \frac{\text{litre}}{37{,}100 \text{ kJ}} = 384{,}000 \text{ litres}$$

tiveness of the investment are primarily the fuel costs and electrical costs.

Table 13-4 shows an analysis of these costs for the most recent year, 1982/83. Two cases were examined; one for oil alone and one for wood alone. The cost of oil was assumed to be $0.28/litre, the price paid by the hospital. The marginal cost of electrical energy has been assumed to be $0.10/kW.h. The total amount of wood consumed, as shown in Table 13-3, was 2,018,800 kg. In Table 13-4 the amount shown is 2,066,000 kg which reflects an estimate of the amount that would have been consumed had the furnace not been shut down for eleven days in October, 1982.

Table 13-4 shows an overall cost of $110 thousand for oil and $63 thousand for wood, indicating an annual saving of $47 thousand.

Another approach that can be used to assess operating costs is based upon the actual heat consumed in the hospital as read on the steam meter. Because wood fuel was not weighed accurately throughout the year and because of a steam meter failure, it was not possible to use the steam meter readings to derive performance data for the complete year. Over the period from December 3, 1982 to May 31, 1983, however, readings of both the steam meter and fuel deliveries were available.

Using the test data contained in Appendix L it is possible to derive an average figure for energy delivered to the hospital of 2.534 MJ/ kg of steam delivered. During the period from December 3, 1982 to May 31, 1983, when 2,073,460 kg of steam were delivered, 5.25×10^9 kJ were supplied to the hospital at the lower heating value of 8750 kJ/kg. During the same period 985 ±15 tons of wood with an average moisture content of 46% were delivered. This quantity of wood chips would contain $7.84 \times 10^9 \pm 0.12 \times 10^9$ kJ. The wood figures are given with plus or minus limits because not all the loads were weighed. This yields an overall input/output efficiency, based on the lower heating value, between 66% and 68%. Assuming an average efficiency of 70%, between 2% and 4% of the input energy can be attributed to such things as radiant and jacket losses, some of which contribute to the building's heat demand.

13.3.2 Labour Impact: An analysis of the income statement of the chip supplier for year ending December 1981, suggests a variable labour and supervisory cost to sales ratio of approximately 48%. On sales of $59,000 (as shown in Table 13-4) this results in a variable labour and

TABLE 13-4

Comparison of Operating Costs

1. Operating Cost - Fuel Oil

Consumption = 392,000 litres

Cost/litre = $0.28

$$\text{Total Cost} = \frac{\$0.28}{\text{litre}} \times 392{,}000 \text{ litres}$$

$$= \$110{,}000$$

2. Operating Cost - Wood Chips

$$\text{Incremental Electrical Consumption} = \frac{3320 \text{ kW.h}}{\text{month}} \times 12 \text{ months} = 39{,}840 \text{ kW.h}$$

Cost/kW.h = $.10

Total Electrical Cost = $4,000

Wood Chip Consumption = 2,066,000 kg

Actual Price Paid = $57,285

Estimated Price Without Eleven Day Shut Down = $59,000

Total Operating Cost for Wood Unit = $59,000 + $4,000 = $63,000

supervisory content of approximately $28,000. Adding in fixed costs paid for accounting and legal services results in a total figure for employment generation of approximately $30,000.

Because of the establishment of a wood chip supply business in the area and the potential fuel cost savings, other conversions from fuel oil to wood chip fuel can be expected. The total potential for employment generation is certainly much greater than the estimate of $30,000 per year for the hospital alone. In general, it can be expected that for every dollar spent by fuel consumers on wood chips, approximately $.50 would go directly to local labour. The equivalent figure for oil, although not calculated would probably be less than $.05 per dollar spent.

13.3.3 Forestry Industry Impact: As noted elsewhere in the report, the hospital will require approximately 245 ha for the supply of wood chip fuel on a sustainable basis. This will result in the application of modern silviculture management practices, on that amount of land. The benefits of these practices will be apparent to other woodlot owners in the area. The forestry impact is discussed in greater detail elsewhere in the report.

13.3.4 Capital Budgeting Analysis: The capital cost of this project will reach about $413 thousand when hydraulically operated doors on the storage bin have been installed. The calculated rate of return on this investment, generated by savings from using wood chip fuel, is expected to be about 12%. However, the rate is very dependent on the assumptions for future wood, oil and electricity prices and maintenance and insurance costs. The assumptions used in arriving at 12% are given in Table 13-5 for two cases.

There are two key differences in the two cases examined. First, oil prices in Case 1 escalate at a rate 1% greater than wood prices (7% versus 6%), after the first three years during which oil prices are constant, whereas oil and wood prices both escalate at 6% per year in Case 2. Second, maintenance and insurance costs for wood are assumed to be $500 higher than for oil in year 1 of Case 1, escalating at 6% per year thereafter, while in Case 2 these costs are assumed to be equal to those for oil.

Since the rate of return is about 12% a discount rate of 12% results in a present value of the expected savings roughly equal to the initial

TABLE 13-5

Financial Analysis

Input	Case 1[3]	Case 2[3]
Capital Cost - $ thousands	413	413
Project Life - years	20	20
Boiler Efficiency[1] - %		
- Wood	70	70
- Oil	78	78
Annual Wood Use - tonnes/year	2056	2056
Annual Oil Use - litres/year	392,000	392,000
Wood Price		
- Year 1 ($/tonne)[2]/($/GJ)	28.40/3.59	28.40/3.59
- Increases - %/a		
. Year 1 to Year 2	8	6
. Future years	6	6
Oil Price		
- Years 1 to 3 ($/litre)($/GJ)	0.28/7.55	0.28/7.55
- Increases after Year 3 - %/a	7	6
Electricity Price		
- Year 1 - $/kW.h	0.10	0.10
- Increases - %/a	8	8
Extra Costs for Wood		
- Maintenance- Year 1 - $	4000	nil
- Insurance - Year 1 - $	1000	nil
- Increases - %/a	6	---
Rate of Return[4] - %	11.7	11.4
Present Value of Savings[5] - $ thousands	403	395
Simple Payback[6] - years	9.5	10.0

[1]Boiler efficiencies are based on the lower heating value of the fuels. For oil the lower heating value used was 37.1 MJ/l; for wood, 7.9 MJ/kg, corresponding to a moisture content of 50%.

[2]Wood price is the average paid in the first year of operation for wood with an average moisture content of 50%.

[3]Case 1 differs from Case 2 in two key aspects. First, oil prices in Case 1 increase at a rate of 1% greater than wood prices after the first three years whereas they rise at the same rate in Case 2. Second, maintenance and insurance costs for wood are assumed to be about $5000 per year higher than those for oil in Case 1 while in Case 2 they are assumed to be about the same.

[4]The rate of return is the discount rate on future savings which results in a present value equal to the capital cost of the unit.

[5]The present values were calculated at a discount rate of 12%.

[6]Simple paybacks do not consider the time value of money (interest) but they are sometimes used as a criterion for comparing projects or investments.

capital cost. The project is therefore self-financing at 12%, excluding any of the external benefits to be discussed later.

Simple payback on the investment would occur by about the end of the tenth year.

Other factors would influence the financial picture for other installations. Units eligible for federal FIRE (Forest Industry Renewable Energy) grants of up to 20% of capital costs would realize a rate of return of about 15% using the oil and wood prices assumed for this analysis. The capital costs of future installations are expected to be lower since they would benefit from experience gained from this project. Tax effects have not been included in the calculations. Their effect would vary with the investor's financial situation, including the ability to write off the investment and the effect of changes in fuel costs on profits, hence taxes.

From a government viewpoint increases in employment, improvements in the forest, including reduced reforestation costs as discussed earlier, and reductions in oil imports would contribute to external benefits not considered in the simple analysis. From both government and owner's points of view the fact that wood is a local resource provides an increase in security of supply which cannot be translated easily into financial benefits.

During the first year of the plant's operation the owner (the P.E.I. Energy Corporation) has accepted charges for one shift per week in recognition of possible additional labour associated with the operation of the wood plant. Discussions with the Chief Boiler Inspector to confirm that an extra shift is really needed are continuing. The cost of an extra shift per week would be about $3500 per year.

The sensitivity of the rate of return to various changes in the assumptions was calculated. A change in oil price of about 1¢/l or a change in wood price of about $2/tonne, assuming such changes would be compounded for the life of the project, would result in a change of about 1% in the rate of return. Such changes are equivalent to a change of about $3.5 thousand in the first year of operation escalated subsequently at about 7% per year.

A change of about $26 thousand in the initial capital cost, equivalent to about 6% of the project cost, would result in a change of about 1% in the rate of return.

13.3.5 Fuel Oil Displaced: As discussed earlier, fuel oil use for the 1982-83 period would have been 392 thousand litres if the wood fired unit had operated for the full year. This figure is within the range of the data in Tables 13-1 and 13-2 for 1980-81 (424 thousand) and 1981-82 (364 thousand) after adjusting them to a 365 day period. The unit is therefore expected to displace in excess of 390 thousand litres of oil per year.

14.0 CONCLUSIONS

From observations made and the review of data available it is concluded that:

14.1 The Anga & Varme wood chip fired heating plant at KCNH performs well and either meets or exceeds the manufacturer's specifications.

14.2 The system is reliable and dependable (one major equipment failure in the course of the year and it is unlikely that this failure would be repeated).

14.3 The system does require the continuous monitoring of the fuel feeding system in order to avoid jams and stoppages.

14.4 The immediate impact on the local forest industry by the introduction of one heating plant is small (1 man year) but the long term effect can be significant in terms of both labour and forest improvement.

14.5 Based on cost alone the cut, skid, cold deck and chip as needed method would appear to be the most economical way of producing wood chip fuel.

14.6 The wood fuel moisture content analysis system is essential if fuel is to be purchased on the basis of dry matter supplied.

14.7 The wood fuel supply system does require further analysis to more accurately measure the delivered quantity of fuel, to determine the optimum size of buffer storage and to reduce as far as possible the number of fuel handlings between cutting and consuming.

15.0 RECOMMENDATIONS

15.1 A boiler feedwater preheat system should be installed in order to meet the manufacturer's specification and to improve overall system efficiency.

15.2 The fuel silo should be equipped with a set of hydraulically driven clamshell doors. These doors would eliminate the threat of a shutdown in heavy rain and would reduce the windchill factor in severe winter weather.

15.3 Consideration should be given to the use of waste heat from the fuel cell for wood chip drying when conducting moisture content analysis. This procedure would eliminate the electric power costs associated with the operation of the wood chip drying oven.

15.4 The fuel supply system requires further analysis in order to reduce the number of times the fuel is handled and to make a final determination on whether fuel storage is necessary.

15.5 In future designs more care should be devoted to the following deficiencies which became apparent in a power failure during warm weather in June 1983:

a) provide adequate lighting on the boiler water level sight glass and in other areas of the boiler room; and

b) provide for adequate boiler room ventilation.